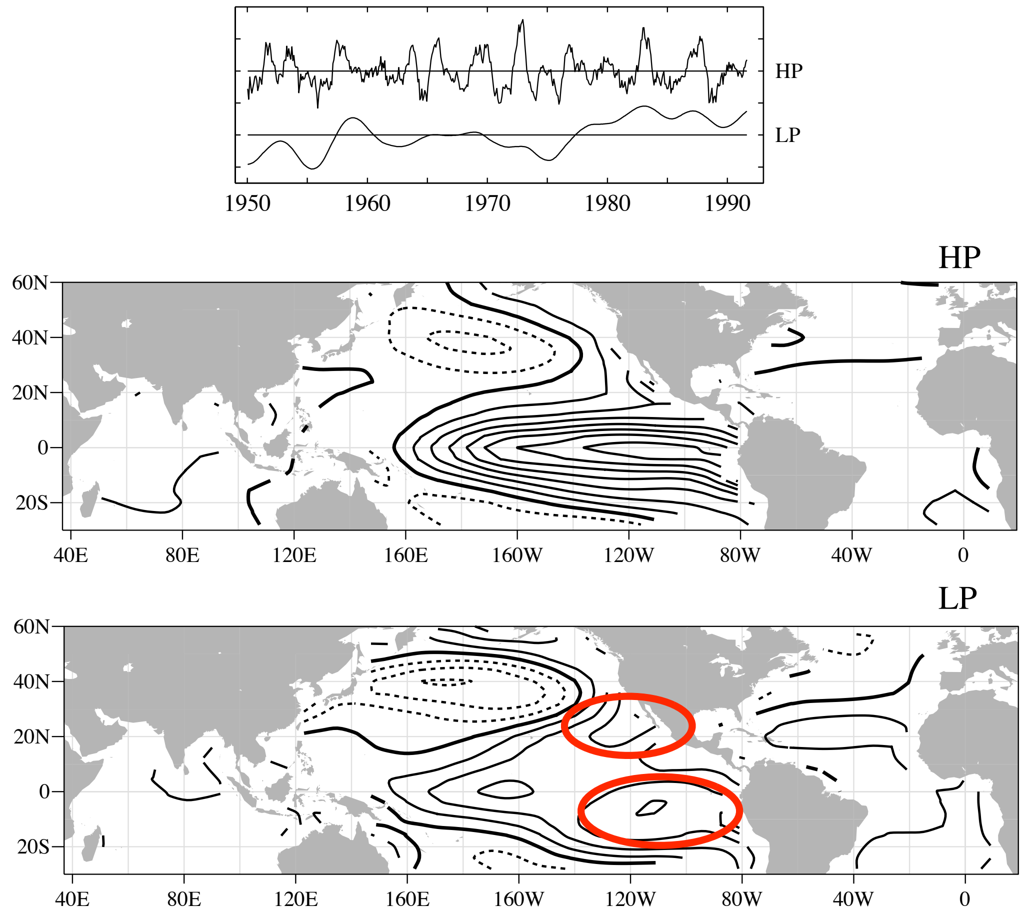
Evidence for Atmospheric Feedbacks in the Subtropical Pacific on Decadal Time-scales

Robert Burgman, Amy Clement, and Junye Chen

Rosenstiel School of Marine and Atmospheric Science,
University of Miami

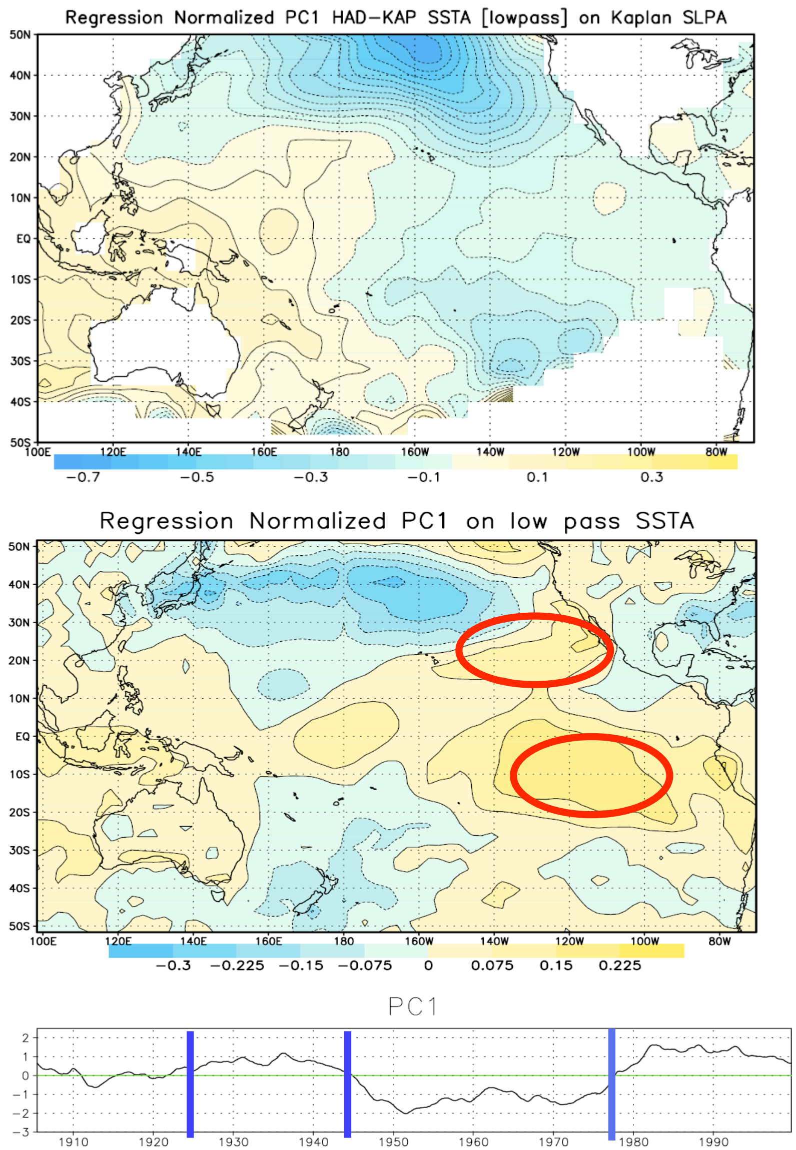
What is the origin of the subtropical SST signal?



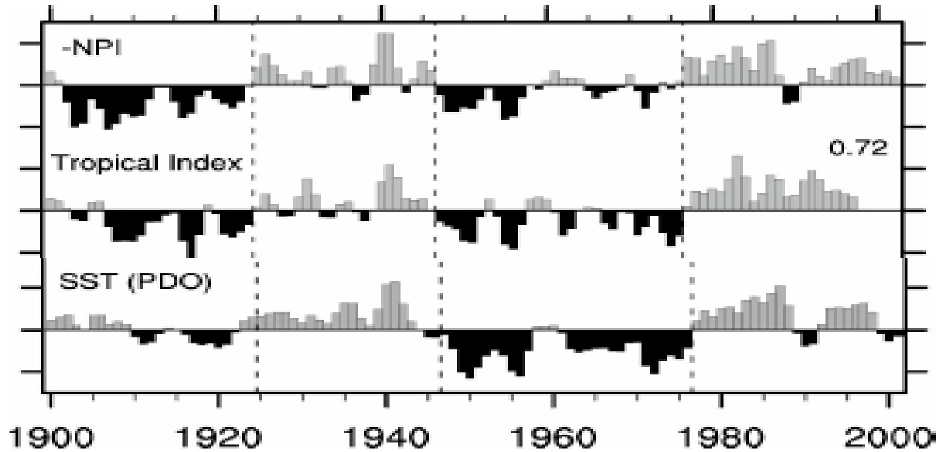
(Zhang *et al* 1997)

Hypothesis: Subtropical signal arises from atmospheric radiative feedbacks

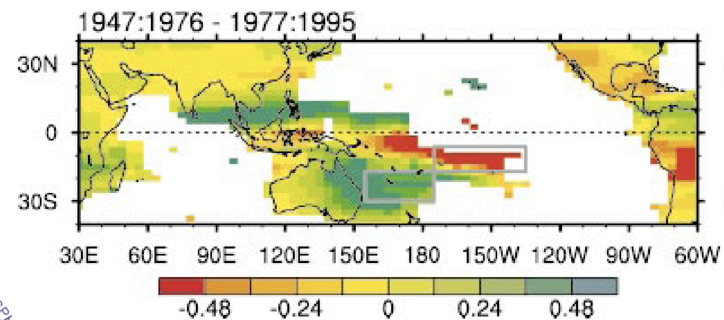
What is the origin of the subtropical SST signal?

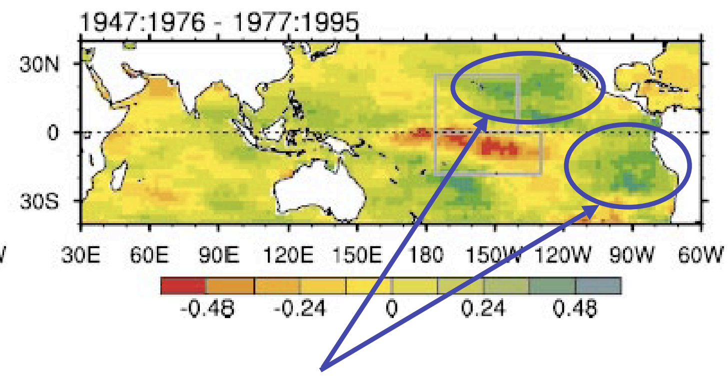


Other surface based observations [Deser et al. 2004]



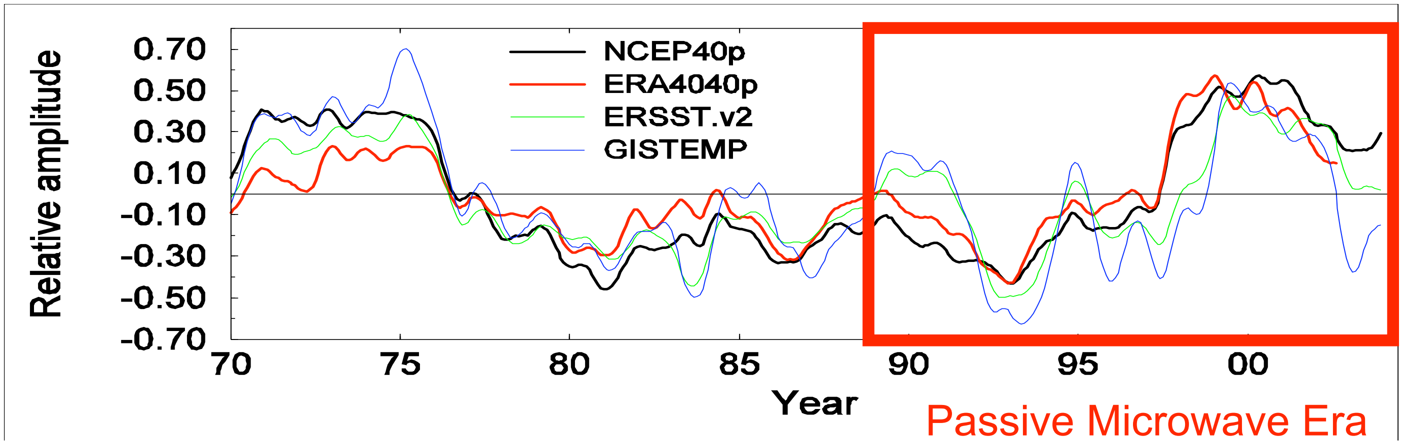
Precipitation **COLD – WARM EPOCHS** **Cloudiness**





Increased cloud cover coincides with colder subtropical SST

A mid 1990's regime shift [Chen 2005]

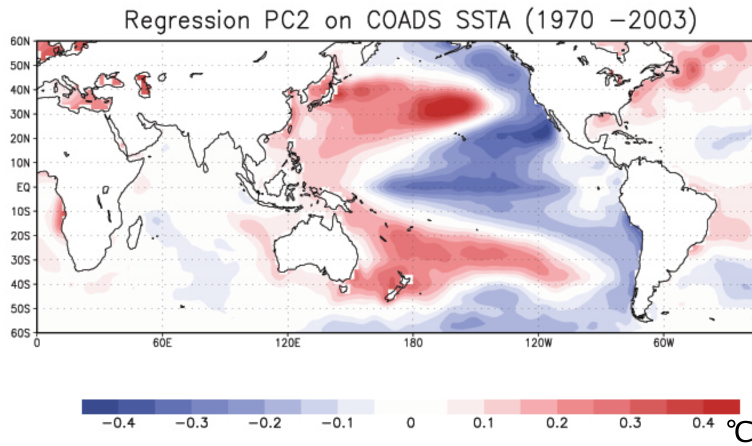


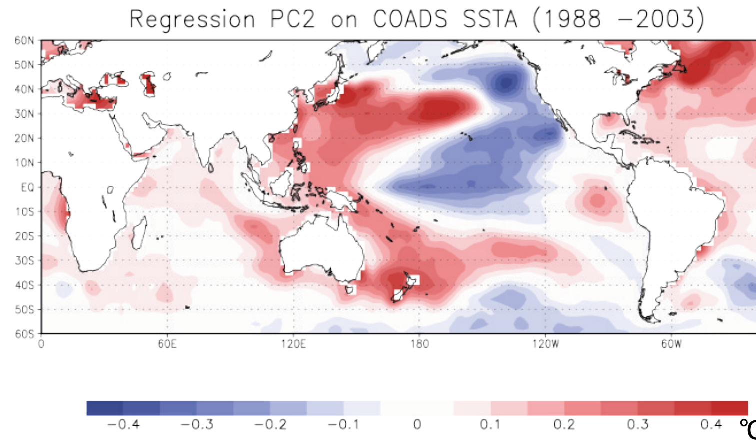
- ENSO removal using extreme cross-correlation at least lag (ECLL)of high pass (Niño3.4) and the parameter at each gridpoint.
- Multivariate EOF of 5 NCEP/NCAR variables on 8 pressure levels.
- EOF1 Global Warming trend (16% variance explained)
- EOF2 Pan Pacific Decadal Variability (9% variance explained)
- Removes stable, linearly related parts of ENSO

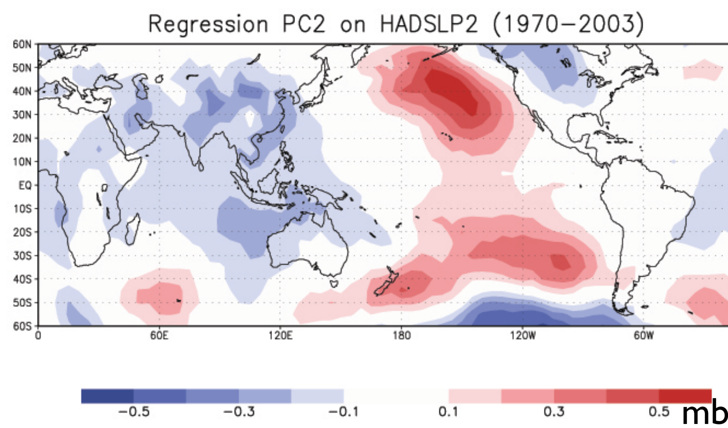
Datasets

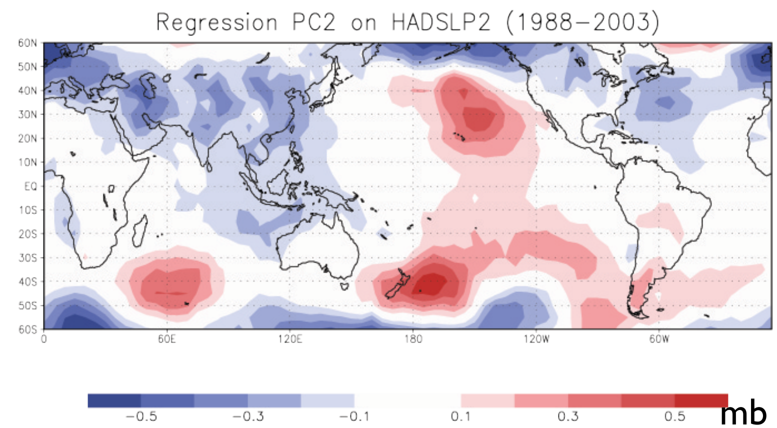
- High Resolution Infrared Sounder (HIRS) OLR (Jan 1979 – Dec 2003)- Retrievals from TIROS-N series operational polar orbiting environmental satellites (Ha-Tien Lee)
- Special Sensor Microwave Imager (SSM/I) V6 water vapor and surface wind speed (Sep 1987 – present) from Remote Sensing Systems
- ERBE/ERBS Nonscanner Edition3 Rev_1 OLR and SWUP
- ICOADS release 2.1 products (Worley et al 2005)
- ERSST-V2 (Smith and Reynolds 2004)

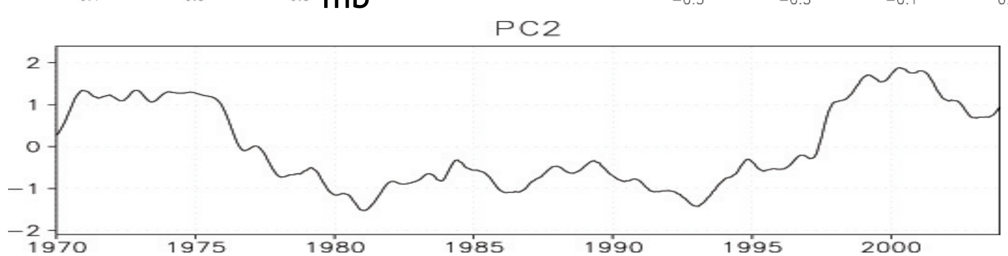
Changes in PDV structure









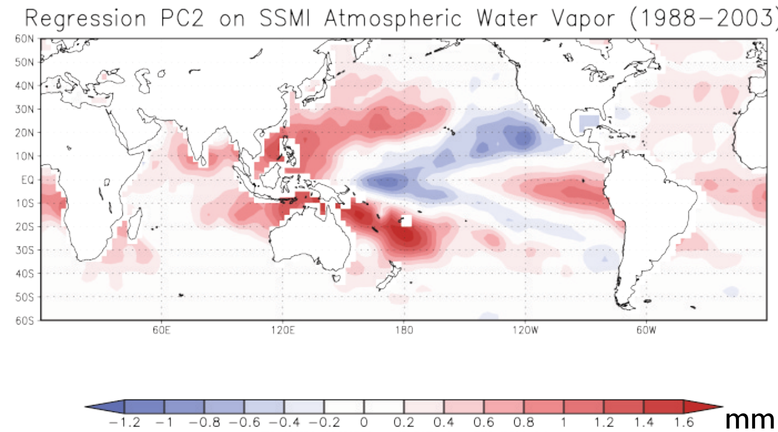


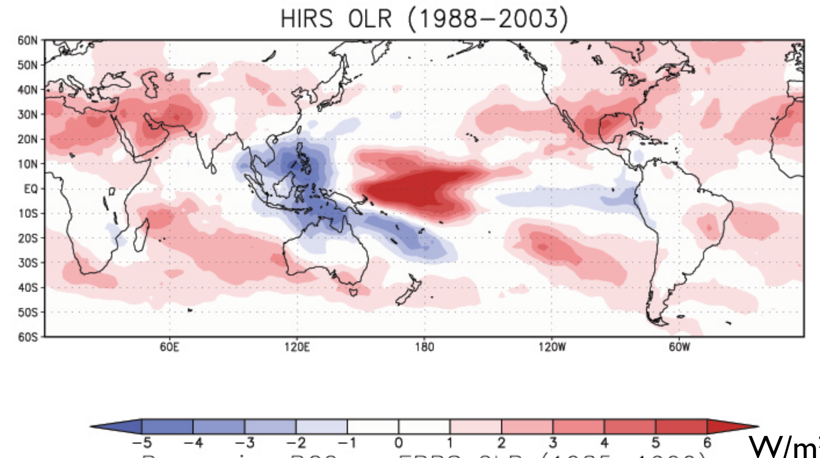
Increase in deep convection in the western Pacific leads to stronger overturning circulation

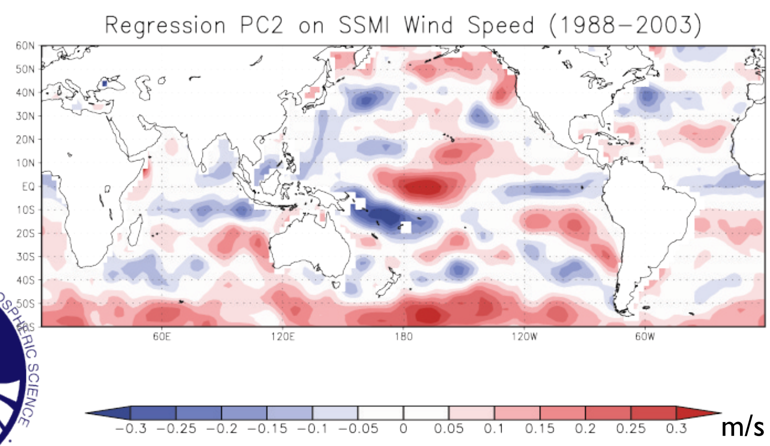
Stronger descending branch leads to dryer subtropical troposphere

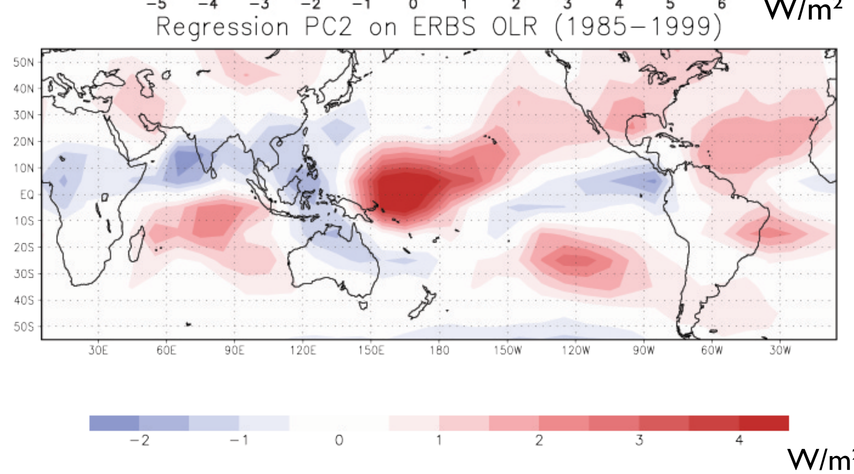
Wind Speed in region of strong subtropical SST signal weakly positive to negative, suggesting turbulent heat flux is not the cause cooling SST

Can SST explain changes in AWV?





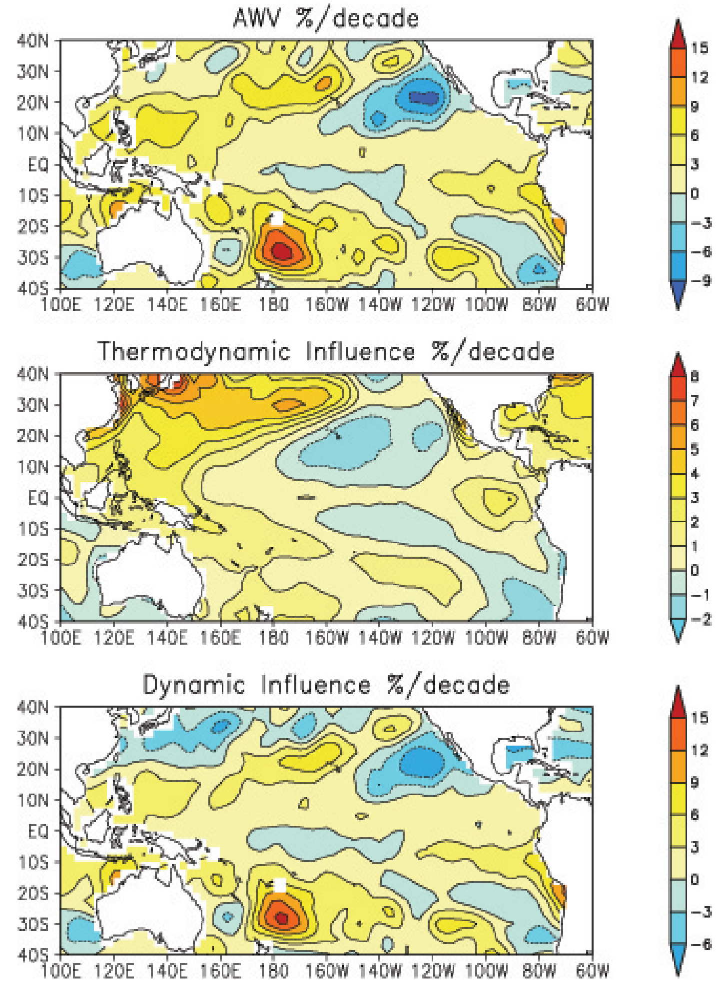




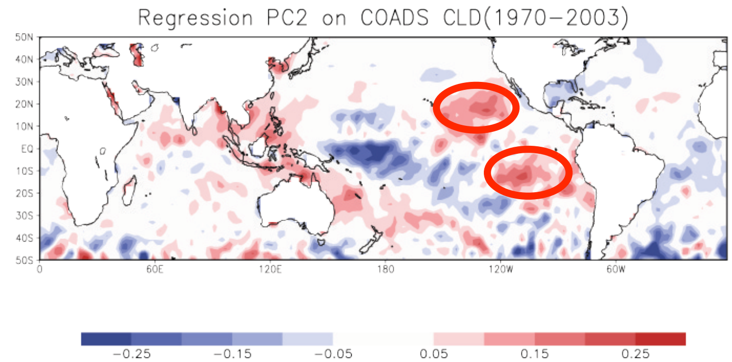
Thermodynamic vs dynamic effects on W

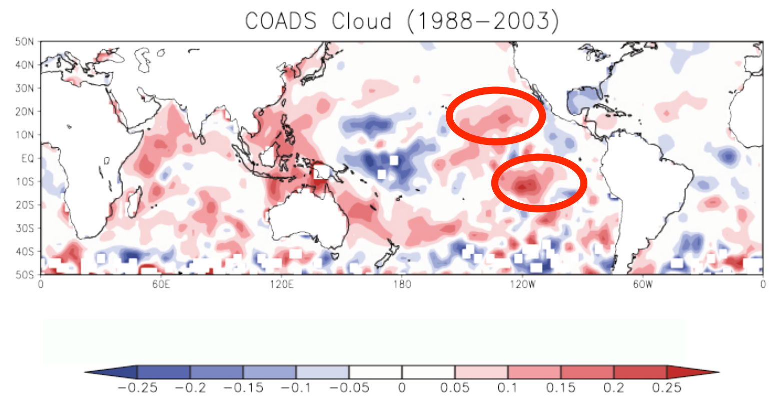
Stephens [1990] found using linearized form of Clausius Clapyron equation, for SST>15℃, SST accounts for 6.5%/K change in W using strictly thermodynamic argument

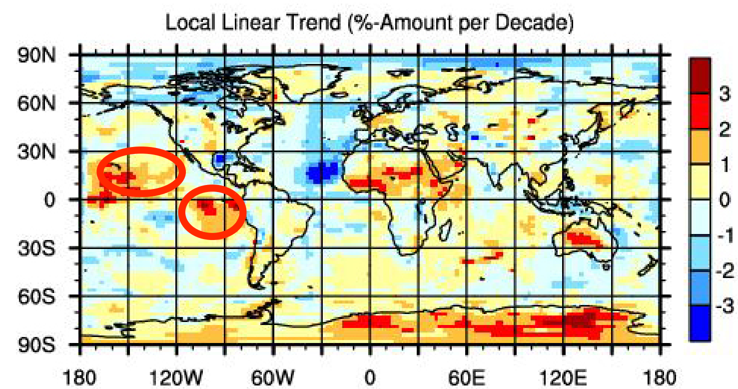
Removing thermodynamics component suggests changes in upper tropospheric humidity are caused , in part, by large scale dynamic effects. [Blankenship and Wilheit2001]



Increased subsidence in the subtropics leads to shoaling of the CBL, may feed back on preexisting SST's by modulating marine stratiform clouds and down welling radiative fluxes at the sea surface [Klien et al 1995, Norris et al 1998, Park et al 2005]







Corrected ISCCP D2 data, linear trend for July 1983 - June 2005 shows increasing cloud amount in subtropics

Norris - personal communication

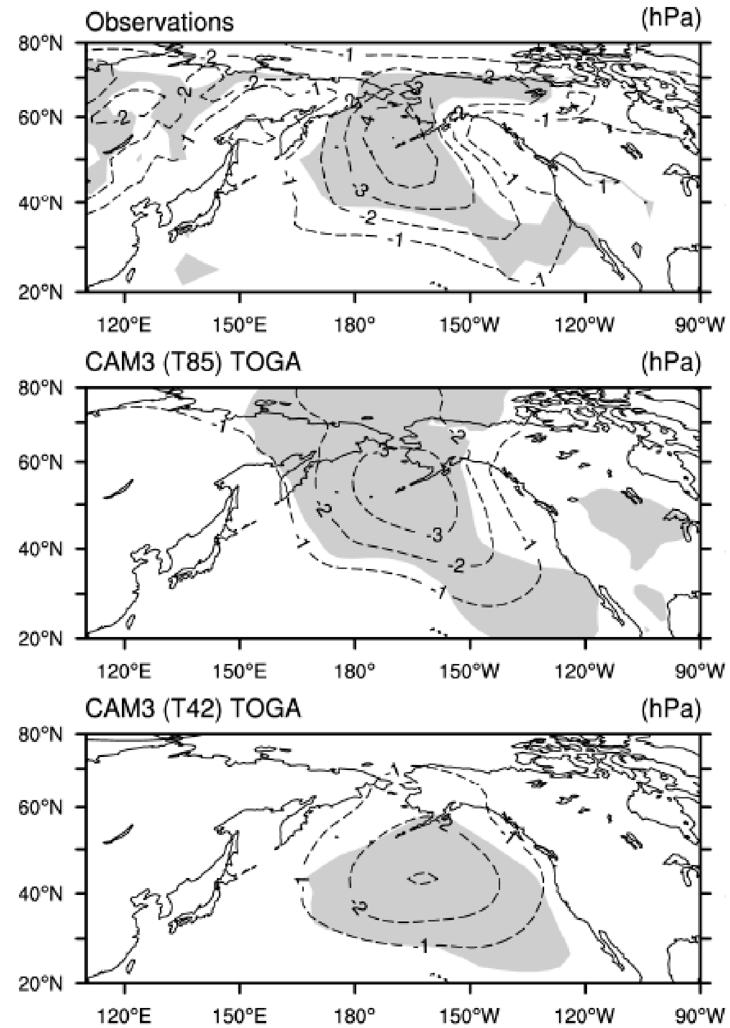
http://meteora.ucsd.edu/~jnorris/isccp_artifacts.html

Remotely forced boundary layer feedback?

CAM3 "TOGA" simulations forced with observed time-varying SSTs in the tropics (20°S - 20°N) and climatological monthly mean SSTs poleward of 30°

Model forced in tropics explains 75% of 4 hPa deepening of Aleutian from 1950-76 to 1977-2000.

epoch (1977-2000) - (1950-76)

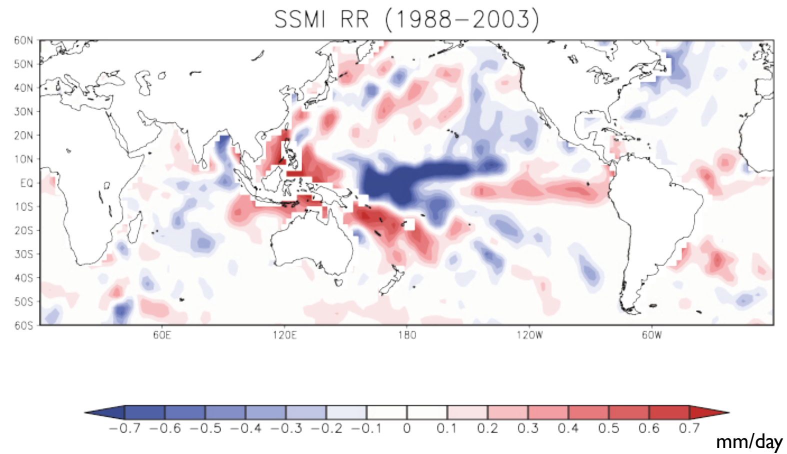


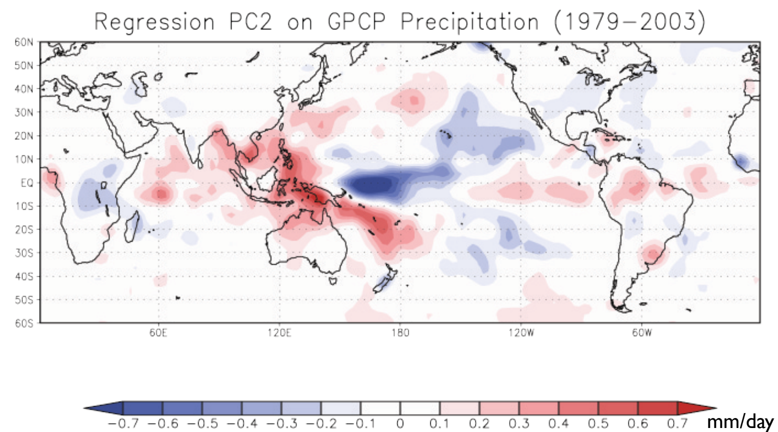
Deser and Phillips (2006)

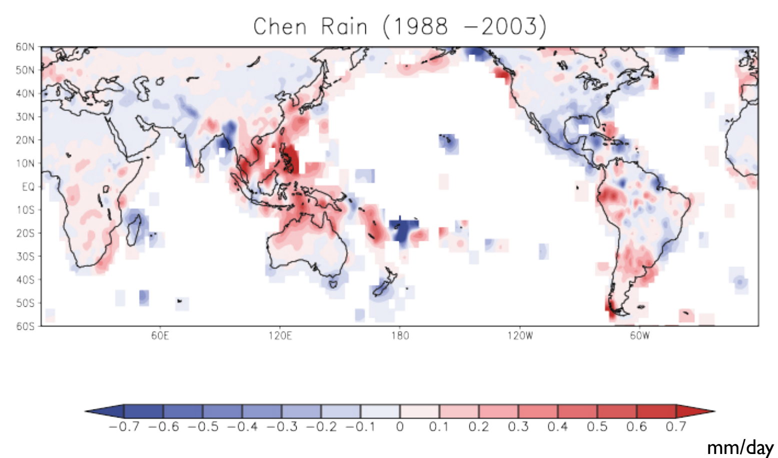
Implications for regional climate

Strong eastern subtropical SLP signal → strong precipitation signal over southwestern US

Cold SST, High SLP, Dry SW US







Implications for global climate

Weaker tropical circulation
[(1) Zhang and Song 2006; (2) Vecchi et al. 2006] consistent with warming subtropics

(1) Zhang and Song 2006

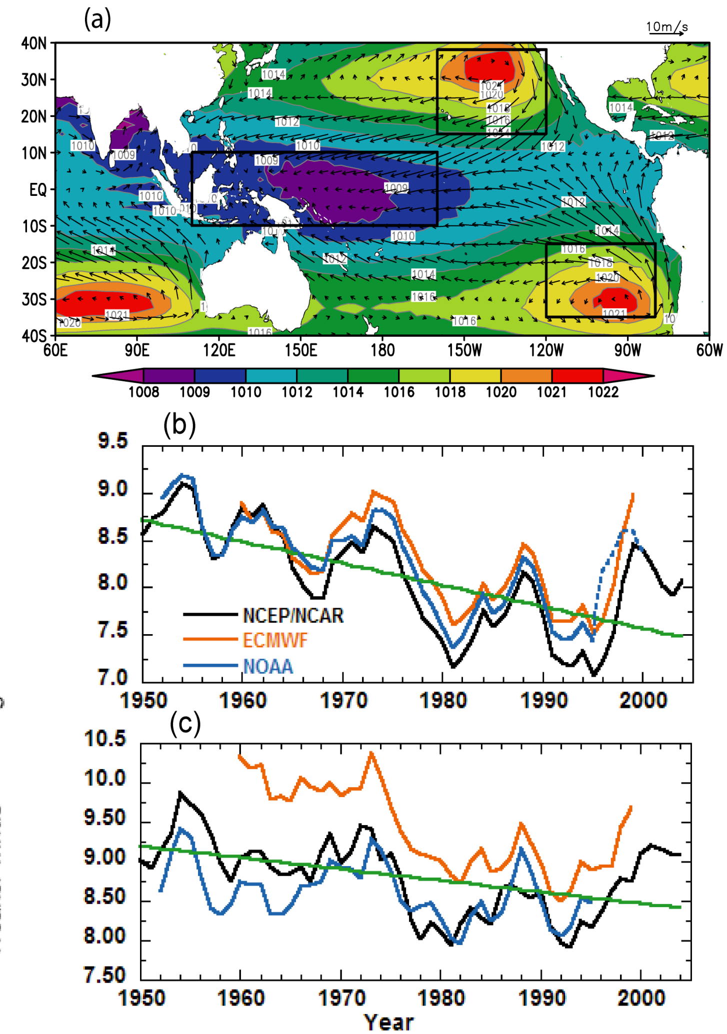
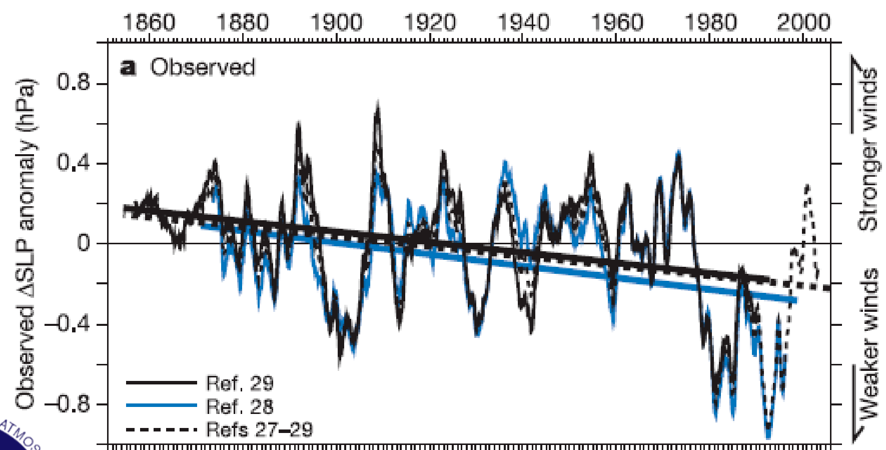


Figure 1

(2) Vecchi et al. (2006)



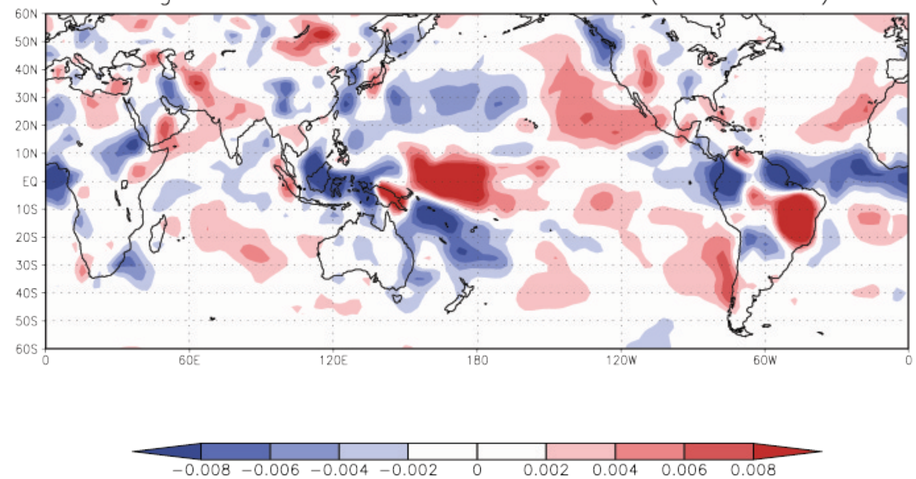
RSMAS
ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE
UNIVERSITY OF MIAMI

Conclusions

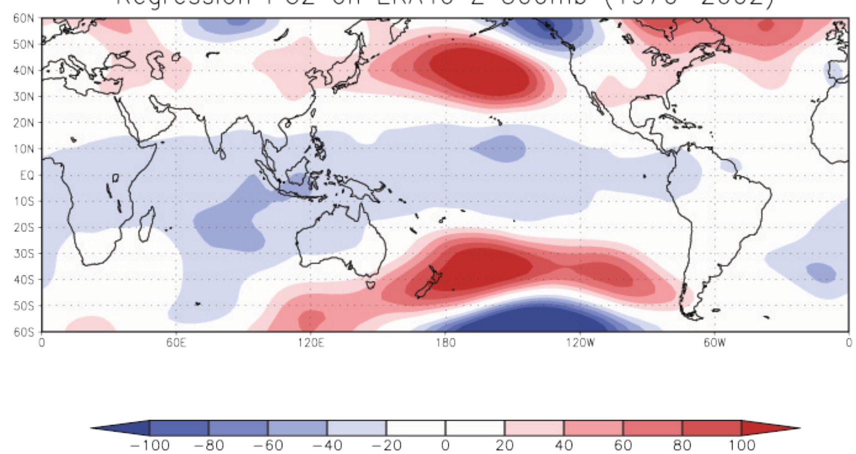
- While previous climate transitions have been shown in surface observations, satellite obs can now reveal possible mechanisms giving rise to regional SST anomalies.
- SLP, OLR and water vapor indicate some atmospheric feedback (water vapor/ boundary layer clouds) contributing to the subtropical SST signal. Surface based observations of previous transitions appear to indicate a low cloud signal.
- SLP signal appears to be remotely forced from the tropics, but better simulated (in SLP) with high resolution model
- Understanding these subtropical processes may have implications for both regional and global climate.

ERA40 regressions

Regression PC2 on ERA40 W 500mb (1970–2002)

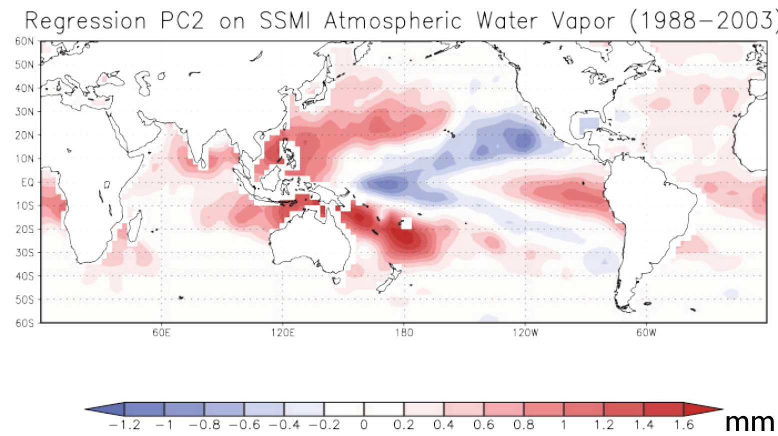


Regression PC2 on ERA40 Z 500mb (1970–2002)

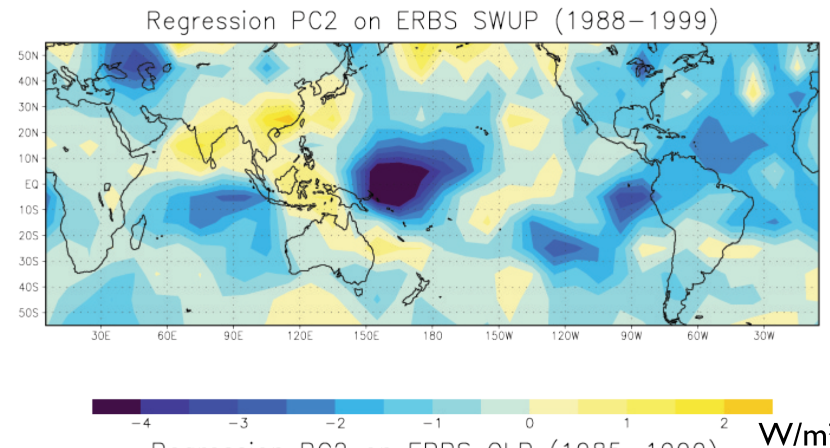


Increase in deep convection in the western Pacific leads to stronger overturning circulation

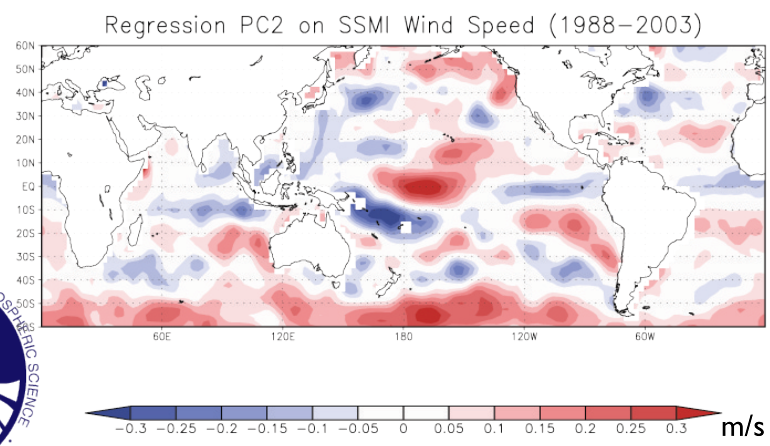
Stronger descending branch leads to dryer subtropical troposphere

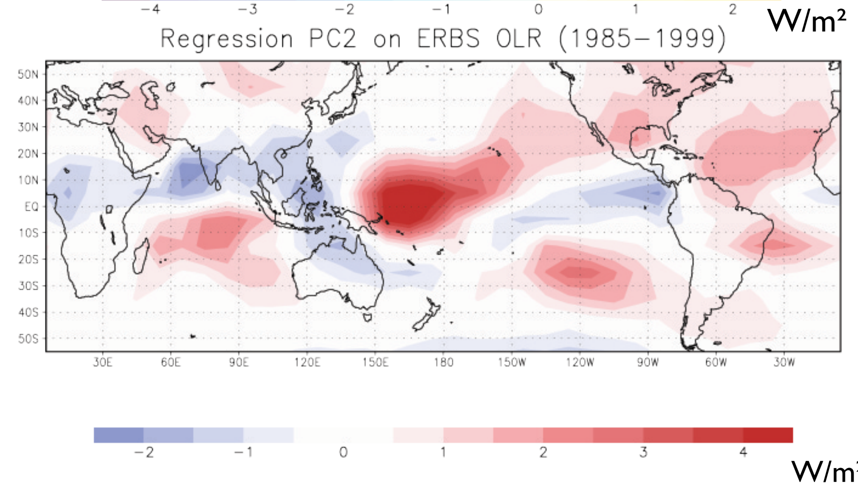


Wind Speed in region of strong subtropical SST signal weakly positive to negative, suggesting turbulent heat flux is not the cause cooling SST

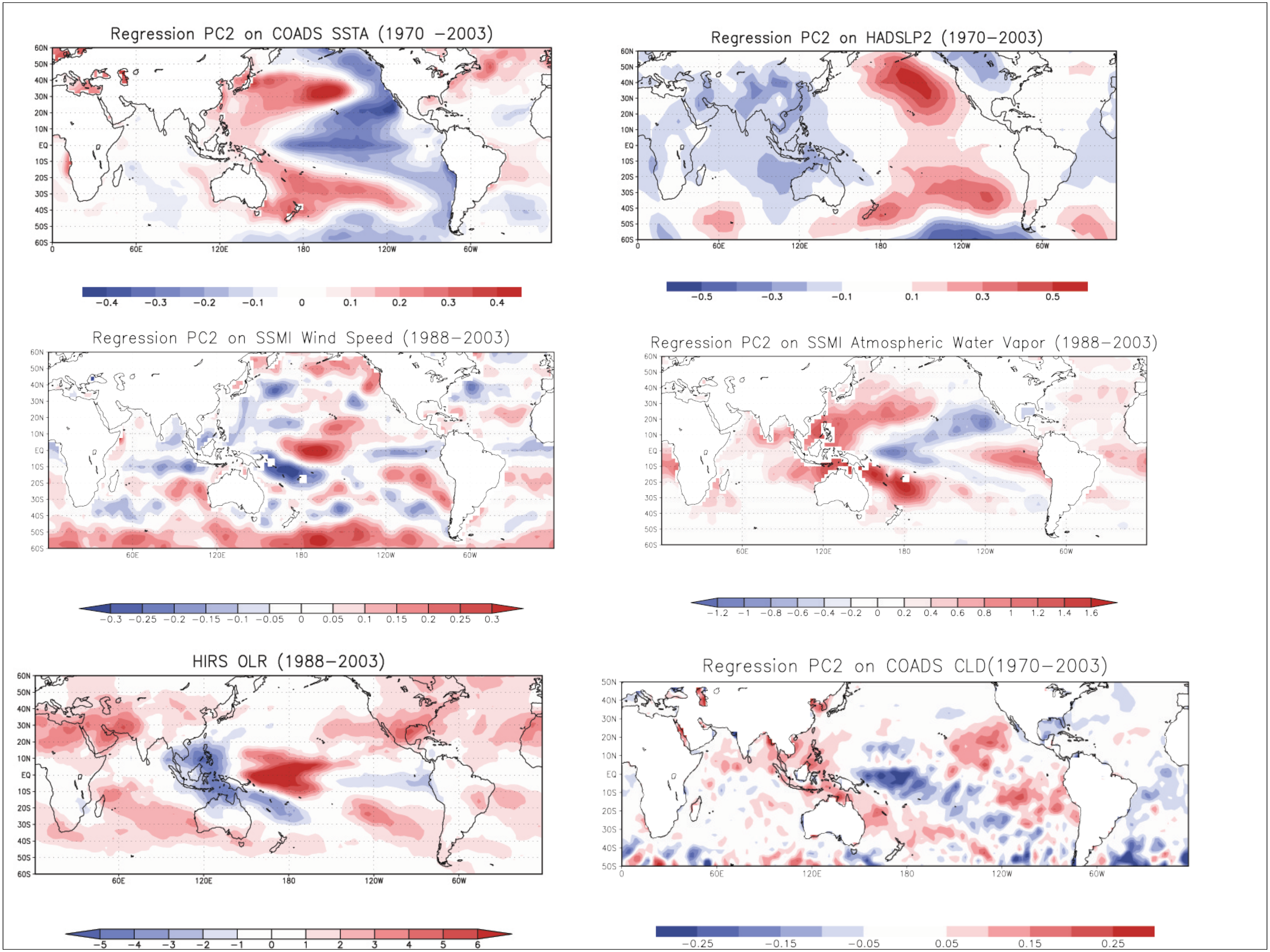


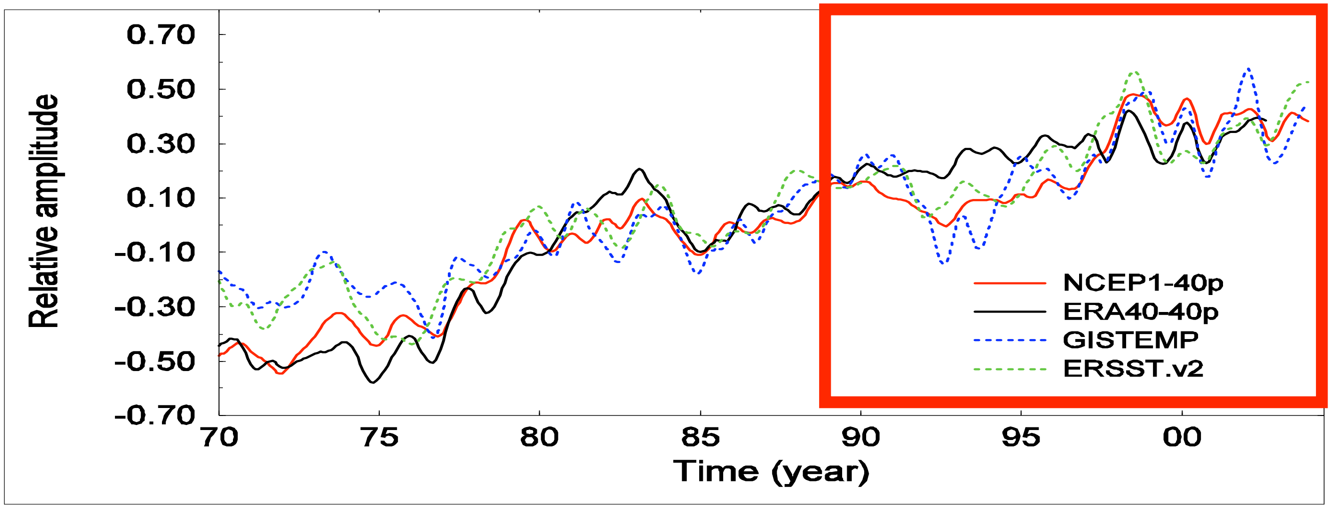
Can SST explain changes in AWV?



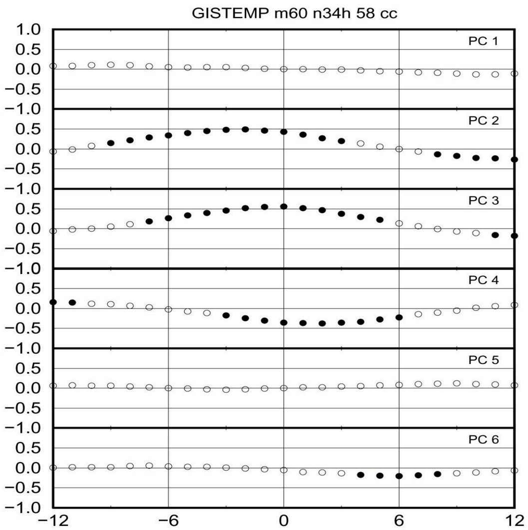


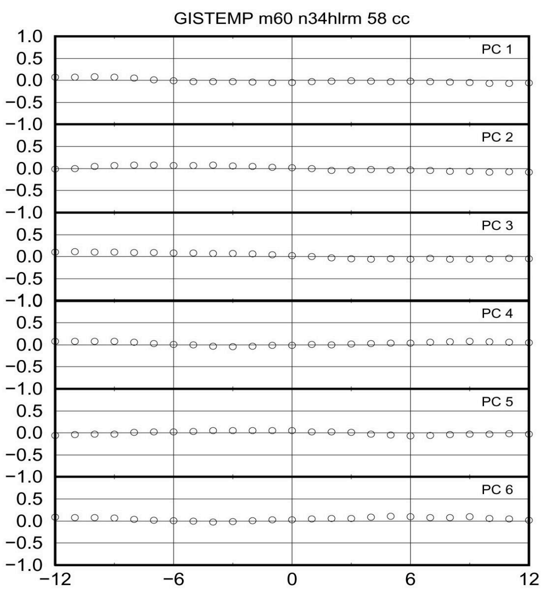
ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE · RSMAS · UNIVERSITY OF MIAMI


Regression PC2 on COADS SSTA (1970 –2003)
Regression PC2 on HADSLP2 (1970–2003)
Regression PC2 on SSMI Wind Speed (1988–2003)
Regression PC2 on SSMI Atmospheric Water Vapor (1988–2003)
HIRS OLR (1988–2003)
Regression PC2 on COADS CLD(1970–2003)



RSMAS
ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE
UNIVERSITY OF MIAMI





$$Tres_{i,m} = T_{i,m} - N34h_{m+j} \times ECLL_i \times \sigma_{T_i} / \sigma_{N34h}$$

EOF analysis on both the original data (top) and ENSO-removed (bottom) data.

The crosscorrelations for a ±12 months lag range between the N34h index and the principal component (PC) timeseries of these EOF analyses are shown.

Filled circle indicate that the crosscorrelation value is confident at the 99% level.

ENSO-removal method

The N34h index and the ECLL relationship between the N34h index and a climate parameter can provide a good approximation for ENSO influence on the parameter. Thus based on it, we can roughly remove the ENSO signal at the grid box level from the spatial-temporal field of that parameter. The first step of ENSO removal is to calculate the ECLL between the N34h index and the anomalies of the climate parameter, *T*, at each grid box. For example, at grid box *i*, we get $ECLL_i$ at lag *j*. Negative lag means the N34h index leads the climate parameter for |*j*| months. Also we calculate the standard deviation of N34h, denoted as σ_{N34h}, and standard deviation of T_i, denoted as σ_{T_i}. So the ENSO-removed *T* at grid box *i* and time *m*, denoted as $Tres_{i,m}$, can be calculated from:

$$Tres_{i,m} = T_{i,m} - N34h_{m+j} \times ECLL_i \times \sigma_{T_i} / \sigma_{N34h}$$

The removal procedure is only applied to grid boxes where $ECLL_i$ is confident above the 99% level.

hypothesis

- Atmosphere amplifies decadal SST pattern: Warming in central pacific (El Nino) causes reduced subsidence in the eastern subtropics, weaker subtropical high, increased water vapor (deeper boundary layer) and warmer SST; and a feedback between these that amplifies warming
- Does the off-equatorial response influence the initial cause? i.e. Warmer off equatorial SST drives westerly wind anomaly which causes the central Pacific warming to persist (via downwelling) → positive feedback
- Consequences:
  - Coupled models- if the subtropical feedback is not active (i.e. if there is no column integrated water/olr/sst response) then there will not be a reddening
  - Global warming trend? Feedbacks in the subtropics matter for climate sensitivity
  - Amip models don't get the feedback right because the signal is coming from the atm & coupling with SST which is not active in fixed sst (you could compare cam amip results with toga runs)
- Issues
  - Enso state varies even within a warm/cold decade- so how does the feedback persist?
  - Threshold? i.e. it takes a really large event to kick off the feedback
  - What causes the change of sign? Timescale?
  - What about soden work (would get drying in subtropics in response to enso)